

# Model 2005 Scintillation Preamplifier

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9231693B

User's Manual



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Canberra Industries, 800 Research Parkway, Meriden, CT 06450  
Tel: 203-238-2351 FAX: 203-235-1347 <http://www.canberra.com>

The information in this document describes the product as accurately as possible, but is subject to change without notice.

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# Notes

# 1. Introduction

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The Canberra Model 2005 represents the latest advance in charge sensitive preamplifiers designed primarily for use with scintillation detectors. The preamplifier converts the ionization charge developed in the detector during each absorbed nuclear event to a step function pulse output whose amplitude is proportional to the total charge accumulated in that event. The pulse decays exponentially with a time constant of 50 microseconds (nominal) to segregate successive events in high count rate applications.

As can be seen in the functional schematic (Figure 1) the first stage functions as an operational integrator yielding an output voltage proportional to the accumulated charge. The second stage functions as a selectable gain differentiator/buffer. Conversion factors of nominally 4.5 mV/pC or 22.7 mV/pC are selected by a jumper plug on the printed circuit board inside the unit. The higher scale factor is especially useful for best signal-to-noise ratio in experiments involving low energy sources. The differentiator circuit includes a pole/zero adjustment to return the unipolar pulse signal to a reference or baseline level without overshoot.

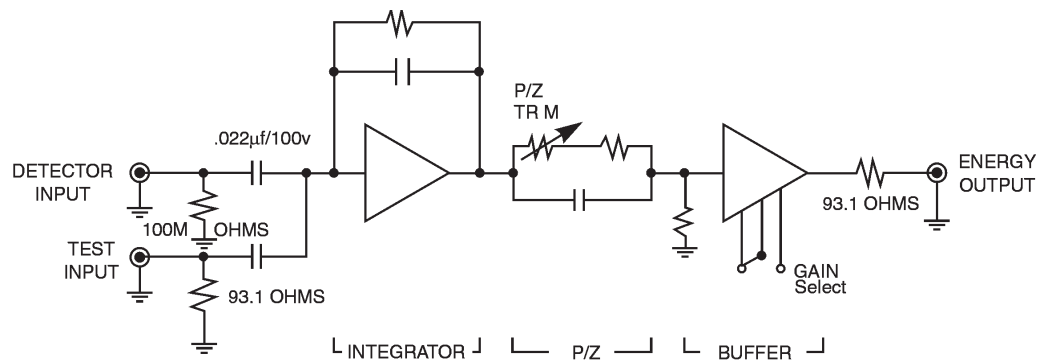


Figure 1 Functional Schematic

The noise level for the Model 2005 is equivalent to less than one femtocoulomb with a source capacitance of 0 pF, using 2 microsecond near-Gaussian pulse shaping, and degrades at less than 0.1 fC/pF. Typical noise performance with other pulse shaping time constants can be seen in Figure 2.

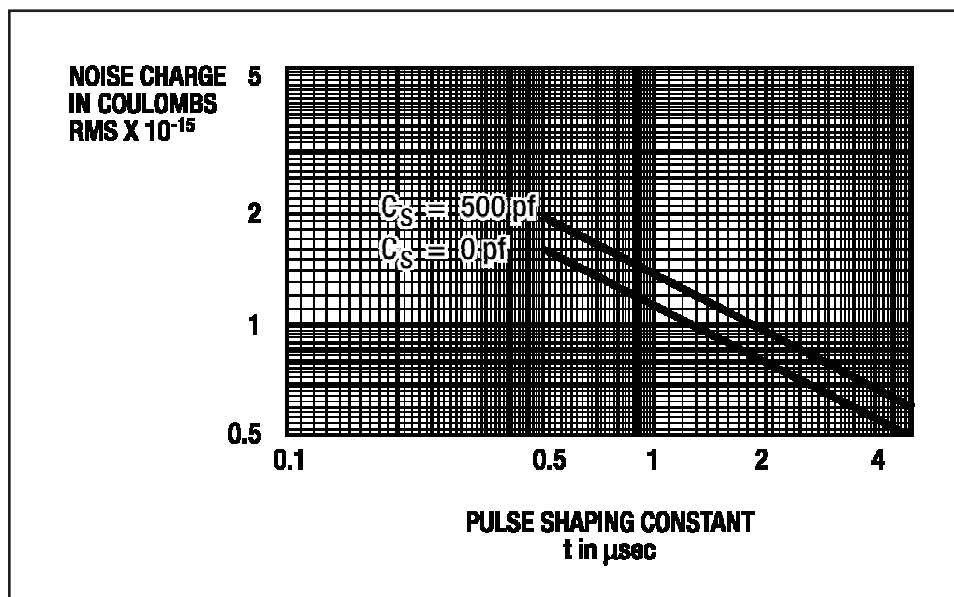


Figure 2 Typical Electronic Noise Behavior

The charge rate capability of the Model 2005 has been demonstrated in excess of  $9 \times 10^{-6}$  coulomb per second. The fast rise time of 15 ns is maintained over a wide range of detector source capacitance and is more than adequate for the charge collection times of NaI (TI) scintillation detectors.

In order to take advantage of the high count rate capability of the 2005, a high count rate main shaping amplifier, such as the Canberra Model 2010 is recommended. Other amplifiers may have count rate limits of their own. Timing analysis may be done with such units as the Canberra Model 1427 ARC Timing Unit or other NIM modules as needs dictate. At low energies, the system timing performance may benefit from the higher gain setting.

A test input is provided on the Model 2005 to assist system setup and simple troubleshooting. Charge coupling through this input is nominally 33 picocoulomb /voltage. The nominal voltage gain through the preamplifier test input is 150 mV/V for the output scale factor of 4.5 mV/pC and 750 mV/V for the output scale factor of 22.7 mV/pC.

Power for the Model 2005 is usually supplied from the associated Canberra pulse shaping amplifier. The power lines are filtered within the Model 2005 to provide high noise immunity. A 3 m (10 ft) power cable is provided with the preamp.

## 2. Controls and Connectors

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This is a brief description of the 2005's front and rear panel connectors. For more detailed information, refer to Appendix A.

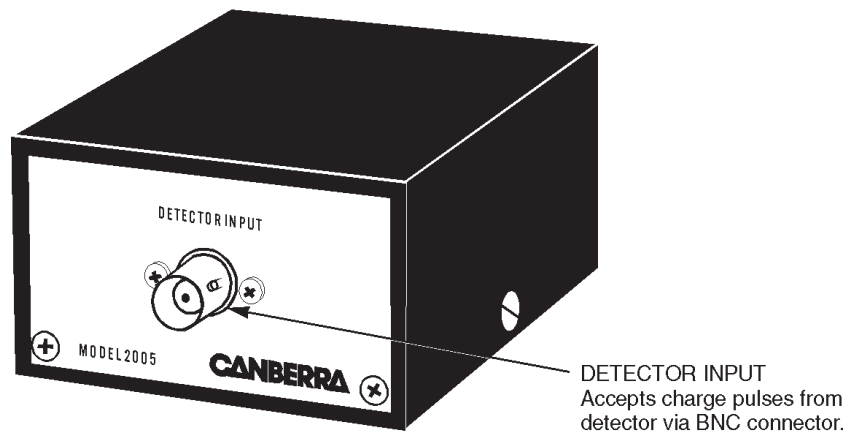


Figure 3 Front Panel Connector

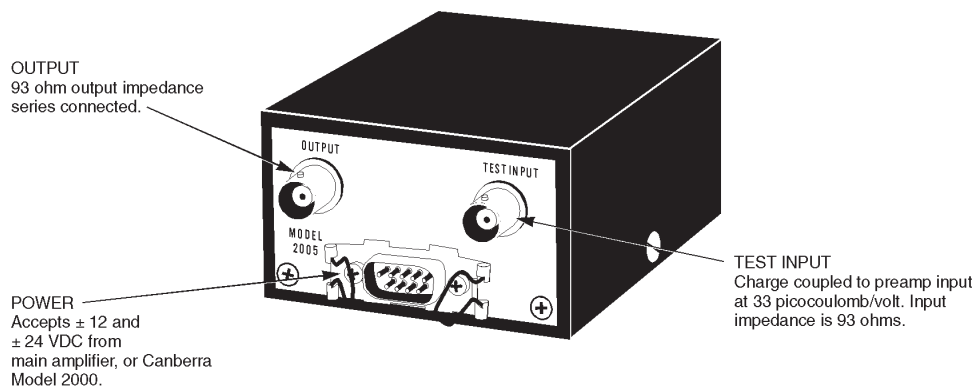


Figure 4 Rear Panel Connectors

## Internal Controls

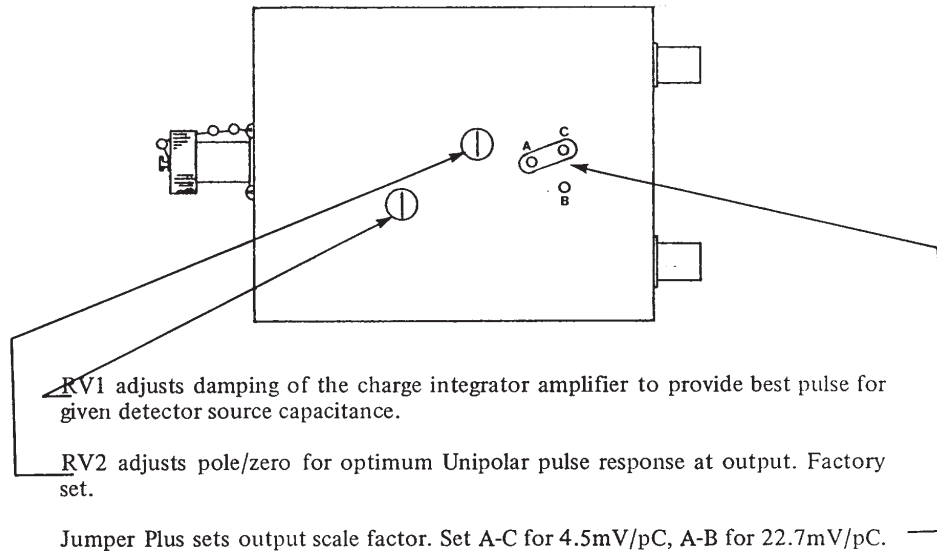


Figure 5 Internal Controls

## 3. Installation

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### Noise Considerations

It must be remembered that any capacitance added to the input of the preamplifier will increase the noise contribution and degrade the rise time of the preamplifier. Input capacitance should be minimized by using the shortest possible interconnecting coaxial cable between the detector and preamp. Choose a cable with minimum capacity per unit length such as RG-62A/U, with 44 pf per meter.

### Mounting

The Model 2005 may be set or mounted in any desired position. Good practice would suggest a location as close to the detector as practicable. Because of the high charge gain and the presence of detector high voltage, the Preamplifier is inherently somewhat microphonic. You may want to use some vibration isolating material at his discretion.

**Note** It is presumed that the unit will be used with the decoupled anode output of a PMT or other low voltage source. Consequently, the voltage limit for the DETECTOR INPUT is  $\pm 100$  V dc. Do not exceed this limit, as the unit may be damaged.

### Preventative Maintenance

Preventative maintenance is not required for this unit.

When needed, the front panel of the unit may be cleaned. Remove power from the unit before cleaning. Use only a soft cloth dampened with warm water and make sure the unit is fully dry before restoring power. *Do not* use any liquids directly on the pramp housing, front, or rear panels.

## 4. Operating Instructions

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The purpose of this chapter is to familiarize you with the Model 2005 Preamplifier and to check that the unit is operating correctly. Since it is difficult to determine the exact system configuration in which the unit will be used, explicit operating instructions cannot be given. However, if the following procedure is carried out, you will gain sufficient familiarity with the instrument to permit its proper use in the system at hand.

The instructions which follow may be best carried out with the Preamplifier on a test bench, separated from the detector. Keep the dust cap secured on the input BNC connector.

Because the input is charge sensitive, and ultra high impedances are involved, the Preamplifier is inherently somewhat microphonic. Testing should only be done with the Preamplifier chassis cushioned on a block of foam rubber and the cover securely fastened to the frame.

The charge gain of the Preamplifier is set by the position of a jumper plug in the approximate center of the printed circuit board. The Preamplifier is shipped with the jumper set from "A" to "C" giving a nominal charge gain of 4.5 mV/picocoulomb, and the nominal voltage gain between TEST INPUT and OUTPUT is 150 mV/V. With the jumper set from "A" to "B" the nominal charge gain is 22.7 mV/picocoulomb, equivalent to approximately 235 mV/Mion-pairs, and the nominal voltage gain between TEST INPUT and OUTPUT is 750 mV/V. Set the jumper to the scale factor desired before use.

### Setup

1. Connect the Preamplifier to a source of low voltage power ( $\pm 12$  and  $\pm 24$  V dc such as from a Canberra main shaping amplifier using the ten foot cable provided. Keep power OFF initially.
2. Connect the output of the Preamplifier to one input channel of a dual trace oscilloscope. Set the vertical sensitivity to 50 mV/div., DC coupled, and the time base to 10  $\mu$ sec/div.
3. Connect the ATTENUATED output of a tail pulse generator (such as Canberra Model 1407 Reference Pulser) to the TEST INPUT of the Preamplifier with a "tee" connection to the second input channel of the oscilloscope. Set the Pulser to (-) output, 90 Hz, minimum rise time, and maximum fall time. Set the vertical sensitivity of the oscilloscope second channel initially at 0.5 V/div., DC coupled.

## Checkout

4. Connect the Pulser NORMAL output to the oscilloscope trigger input and set the oscilloscope tip for external triggering on the (+) slope.

## Checkout

1. Switch the main power ON.
2. Adjust the Pulser output for a 2 V peak negative pulse on the scope. Observe the Preamplifier OUTPUT to be approximately 300 mV peak positive (for 4.5 mV/pC scale factor) or 1.5 V peak positive (for 22.7 mV/pC scale factor).
3. Reduce the Pulser output to 20 mV peak, and set the polarity to negative.
4. Connect the Preamplifier OUTPUT to the INPUT of a low noise Spectroscopy Amplifier (such as Canberra Model 2010) and move the oscilloscope first channel input to the Amplifier UNIPOLAR OUTPUT. Set the Amplifier to 2  $\mu$ sec shaping.
5. Connect an AC Voltmeter to the Amplifier UNIPOLAR OUTPUT on the rear panel. If the Voltmeter is a true RMS type adjust the Amplifier COARSE and FINE GAIN for a peak output pulse of 6.6 V. If the voltmeter is an average reading type calibrated to read RMS on a sinusoid, set the Amplifier gain for a peak output pulse of 7.5 V. The meter will now be calibrated to read 10 mV = 1 fc RMS of system noise.
6. Switch the Pulser OFF, disconnect it from the Preamp TEST INPUT and place the dust cap on the DETECTOR INPUT. Read the 0 pf noise of the Preamp plus Amplifier on the voltmeter. Note: A slightly lower reading is obtained using the higher scale factor ( jumper plug from "A" to "B") by virtue of the improved noise weighting between Preamp and Amplifier.
7. Noise tests may be made for simulated detector source capacitances by adding test capacitors (properly shielded) to the input. For the Model 2005, the capacitors should be a low noise type, preferably porcelain, mounted in a BNC connector and shielded.

## Performance Adjustments

While the Preamplifiers have been carefully calibrated at the factory, you may choose to change either the pole/zero or rise time/damping adjustments for specific experiments.

The following procedures detail the most effective method of making the desired adjustments. Please read Chapter 3, *Installation*, and the beginning of this chapter before making any adjustments.

## Equipment Required

The following equipment is required

1. Function Generator providing variable 0-10 volts square wave output, with rise time less than 25 nsec, and a sync output (HP 3310, Data Dynamics 5109 or equivalent).
2. Calibrated Oscilloscope, rated DC 150MHz minimum (Tektronix 454, 475 or equivalent).

## Pole/Zero Adjust

The following method uses the Function Generator square wave output to calibrate the Pole/Zero precisely, in lieu of the more common approximations made using, various sources presented to the detector. The adjustment is properly an electrical one and is not influence by detector variances. Hence, it is usually set just once. The same technique is equally valid for the Preamp/Amplifier interface in adjusting the Amplifier's input differentiator Pole/Zero. That setting does change between each Preamplifier and Amplifier, and the instructions which follow provide the optimum setting here as well.

1. Verify Bin power is OFF before making connections to preamp. Scope and Function Generator Should be ON and warmed up. Amplifier should be installed in Bin or wired to Bill power source.
2. Connect preamp power cable between Preamp and Amplifier.
3. Connect shielded cables BNC/BNC between:
  - Preamp OUTPUT and scope channel B input;
  - Function Generator SYNC output and scope external trigger input;
  - Function Generator signal Output and "tee" inserted at scope channel A input;

## Performance Adjustments

- Scope channel A “tee” and Preamplifier TEST INPUT.

### 4. Equipment Settings

Function Generator output . . . . . 1 volt pk-pk square wave

Scope Frequency . . . . . 500Hz

Scope Channel A . . . . . 0.5V/div., DC coupled

Scope Channel B . . . . . 0.1 V/div. , DC coupled

Scope Display . . . . . Alternate, ext. Triggered, 200  $\mu$ sec/cm

Set jumper plug inside Preamplifier to “A” and “C”. Apply power to the Bin power supply.

5. Apply power to the Bin power Supply. Observe scope dual trace for display as shown in Figure 6.

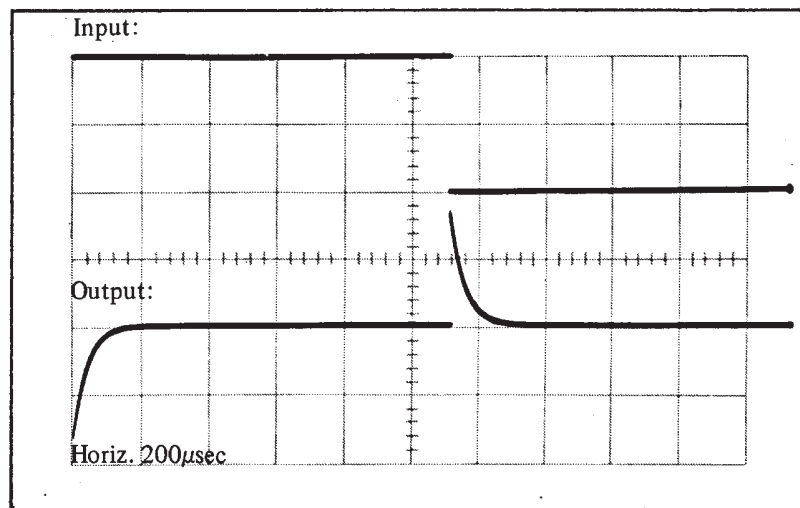
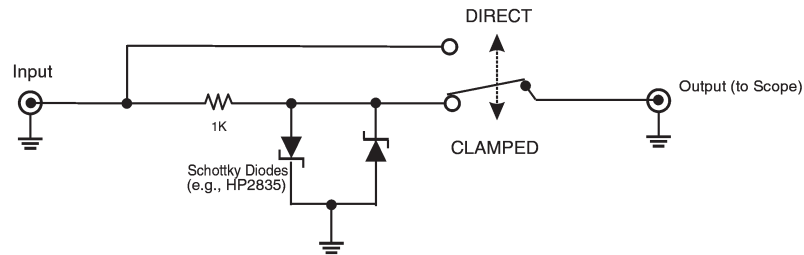


Figure 6 Model 2005 Input and Output Waveforms

6. Set scope to display Channel B only and decrease sensitivity to 0.5V/div. Increase Function Generator level for a display of approximately  $\pm 1.5$  V peak (3 V pk-pk).

The following clamp circuit will be very useful in establishing the Pole/Zero trim. It should preferably be mounted in a miniature box (e.g. Pomona 2417, with BNC plugs to attach directly to scope input).



7. Install Schottky clamp box on input to Channel B, reconnect coax cable. Set switch to DIRECT and verify wave form essentially same as in Figure 6.
8. Set switch to CLAMPED, change scope to 20 mV/div. (vert.) and 1 ms/div. (horizontal). Set Function Generator frequency to 100 Hz. Now adjust RV2 for best pulse response as illustrated in center trace of Figure 7. Proper compensation requires a flat line, without overshoot or long tailing. Preamp Pole/Zero is now set precisely.

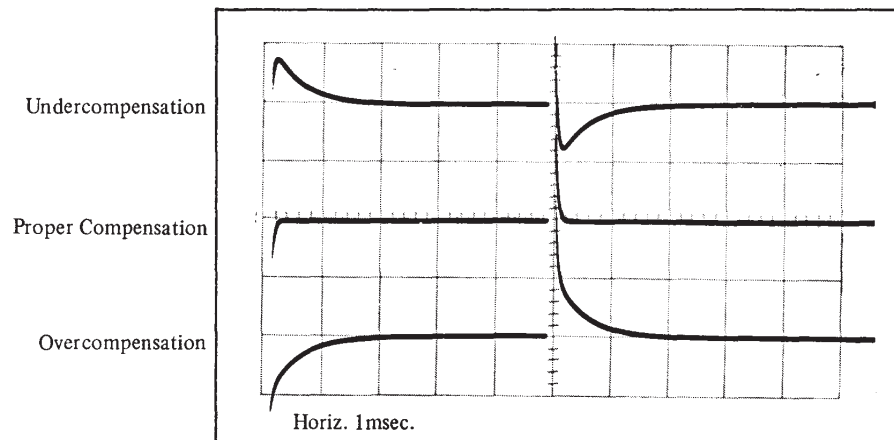


Figure 7 Model 2005 Preamp Pole/Zero Adjust

## Performance Adjustments

9. Reduce Function Generator output to a minimum, set frequency to about 500 Hz. Move coax cable at the Preamp OUTPUT and reconnect to Amplifier UNIPOLAR OUTPUT. Add a coax cable between Preamp OUTPUT and Amplifier INPUT.
10. Set Amplifier controls as follows:  
  
Gain ..... X100 (using coarse and fine controls)  
  
Shaping ..... 2 microseconds  
  
Range ..... 10 volts  
  
Input Polarity ..... positive  
  
Output Polarity ..... positive  
  
Restorer ..... OFF
11. Set switch on Schottky clamp box to DIRECT. Adjust Function Generator for a scope Channel B display of 20 pk-pk, using 5 V/div. scale and a time base of 200  $\mu$ sec/div.
12. Set switch on Schottky clamp box to CLAMPED, change scope display to 100 mV/div. and adjust the Amplifier Pole/Zero front panel trim pot for best pulse response as shown in Figure 8. Amplifier Pole/Zero is now set precisely.

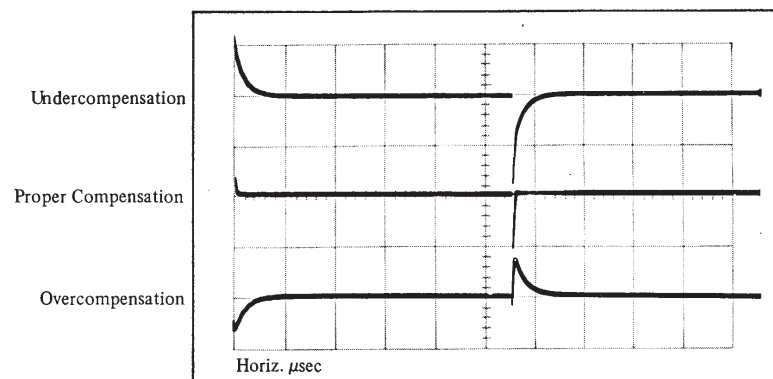


Figure 8 Model 2005 Amplifier Pole/Zero Adjust

## Common Operating Problems

All of the many possible contributors to less than optimum performance cannot be listed here. The purpose of this section is to note the usual causes of loss of resolution and to suggest corrective steps.

Do not expect to diagnose all problems with a detector, a Preamplifier, a main Amplifier and a multichannel analyzer. The system records results, it does not necessarily lead to the identification of causes. A good, modern oscilloscope (Tektronix type 453, 454, 465 or 475) will be needed. Also, a high quality tail pulse generator (Canberra 1407 or equivalent) will be extremely useful.

However, the simplest test is to connect your detector, apply bias, present a source, and accumulate data. Be sure a Pulser is not feeding the Preamplifier while the data is accumulating or resolution loss may result. If the results obtained are far different from what is expected, it then becomes necessary to troubleshoot the system.

First, observe the Amplifier output on an oscilloscope at various time base and amplitude settings. Is the Amplifier properly pole/zero canceled? Do the output pulses cause undershoots that persist for longer than two or more main pulse widths? The Canberra Model 1413 and 2010 Spectroscopy Amplifiers have a built-in DC Restorer. Set the main Amplifier pole/zero cancellation by the procedure given in the Amplifier manual, or refer to "Performance Adjustments" on page 8.

The next step is to remove all sources and, with the detector still connected and bias applied, to apply a test pulse to the TEST INPUT of the Preamplifier. Make sure the pulser polarity is correct. Set the amplitude of the pulser so that its peak occurs near the region of the peak of the source previously used.

Observe the output of the amplifier without DC restoration. Note that the amplifier is not properly pole/zero canceled for the pulser feeding the Preamplifier (due to the extra time constant of the pulser). This is of no consequence for a pure pulser input. Are the baseline fluctuations of 60 to 120Hz frequency? A ground loop is indicated. Insert all system line plugs into the same outlet. Or, are the baseline fluctuations of random frequency between 10 Hz and 15 000 Hz? If so, clap your hands near the detector and look for increased noise of this type. The area may be too noisy, causing microphonic problems.

If low frequency noise still is a serious problem, it may be necessary to use the Low Rate mode of the Canberra main amplifier's built-in DC restorer.

If high frequency noise is observed, is it random or periodic? Periodic noise is a sign of electronics failure; isolate the cause by observing the Preamplifier OUTPUT. Is the same pattern observed or is the problem in the main Amplifier? Random high frequency noise may be detector load resistor or input capacitor breakdown.

## Common Operating Problems

Next, accumulate a pulser peak on the analyzer. Calculate its resolution. Repeat with the detector removed and the input connector of the preamplifier shielded. You now have three resolution figures available for essentially equal energy peaks: source; pulser and biased detector connected; pulser without detector connected. Denote these by  $R_S$ ,  $R_D$ , and  $R_E$ , respectively.

If  $R_E$  is acceptable, but  $R_D$  is greater than 1 femto coulomb RMS plus  $1 \times 10^{-18}$  coulomb RMS per pf of detector and connection capacitance, then the problem is either in the detector (microphonics, excess leakage current noise, breakdown due to moisture or grime on the detector output connector) or in the Preamplifier (leaky input capacitor, dirty or moist detector load resistor, dirty or moist detector input connector).

If  $R_E$  and  $R_D$  are acceptable, but the live spectrum ( $R_S$ ) is not as good as expected, the problem is probably in the detector (bad detector, poor charge collection, insufficient bias) or in the electronics following the Preamplifier (count rate too high, improper Amplifier pole/zero cancellation, wrong main Amplifier time constant, wrong position of restorer, wrong Amplifier shaping-bipolar vs. unipolar, improper Amplifier shaping for the ADC being used, ADC cannot take the count rate, Amplifier or ADC drift).

These many alternatives are not easy to check. Substituting, one-by-one other detectors, Preamplifiers, Amplifiers and multichannel analyzers may help pinpoint the problem. Checking the above common problems will aid in spotting the source of the trouble.

Going through the steps mentioned above help to eliminate obvious problems and will provide a good starting point for the final troubleshooting step. For additional support contact Canberra.

## 5. Circuit Description

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(Refer to schematic B-17370)

The Model 2005 Spectroscopy Preamplifier functionally consists of three stages: a charge-to-voltage converter (integrator), a differentiator (p/z), and a buffer section.

The integrator may be analyzed in terms of conventional operational amplifier theory where Q1 through Q6 function collectively to provide a large voltage gain, low output impedance, and high input impedance. C15 closes the loop as the feedback impedance  $Z_f$ , while C14 acts as the source impedance  $Z_s$ . The closed loop input (Q1 gate) to output (Q4 emitter) voltage gain may then be calculated as

$$A_v = \frac{Z_f}{Z_s} = \frac{C14}{C15}.$$

Specifically, the input FET operates at a fairly low drain-to-source voltage (4 V dc nominal) and a bias current conducive to high signal gain and low noise (5-10 mA). R1 defines this current. R4 is a level shifter. AC current flows from Q1 via C3 into Q3. Gain is increased as a consequence of using an active current source (Q5) with an output impedance of several megohms as a load to the collector of Q3. At this point dominant pole compensation is provided by C4, C5, and RV1 to stabilize the voltage gain with respect to frequency.

Buffer action is provided by emitter follower Q4 and constant current source Q6 to drive the next stage. R14 furnishes a DC feedback path and in combination with C15 defines the integration time constant.

The pole/zero stage acts to compensate this same time constant by the use of RV2, R27 and C6. R18 and C6 are responsible for adding the nominal 50 microsecond tail pulse. Such an arrangement keeps the pulse precisely unipolar and aids in achieving the best resolution and overload recovery possible.

The buffer stage consisting of Q7 through Q11 is again configured using the operational amplifier approach. Q7 and Q8 are biased as a differential pair with Q9 providing voltage gain, level translation and a voltage swing of  $\pm 10$  V. D2 and D3 provide the static forward bias for the push-pull emitter follower outputs Q10 and Q11. The output transistors provide current gain for driving cable lengths without pulse degradation. The loop is closed by either R21 or R22 depending upon which gain option is chosen.

If the higher gain is chosen, then:

$$A_v = \frac{R_s + R_f}{R_s} = \frac{R_{20} + R_{22}}{R_{20}} .$$

When the lower gain option is chosen, then:

$$A_v = \frac{R_s + R_f}{R_s} = \frac{R_{20} + R_{21}}{R_{20}}$$

as dictated by classical operational amplifier theory.

Standard LC decoupling of the supply lines is employed to minimize problems caused by noise pickup and induction effects in the power cable.

# A. Specifications

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## Inputs

DETECTOR INPUT – Accepts charge pulse from scintillation/photomultiplier detector.

TEST INPUT – Charge coupled to preamp input at 33 pC/V;  $Z_{in} = 93 \Omega$ .

## Outputs

ENERGY OUTPUT – Inverted tail pulse; rise time as in Table 1; 50  $\mu$ s fall time constant, up to  $\pm 10$  V;  $Z_{out} = 93 \Omega$ ; direct coupled.

| Table 1                    |                       |                          |
|----------------------------|-----------------------|--------------------------|
| $C_{source}$ in Picofarads | Noise in Coulombs rms | Rise Time in Nanoseconds |
| 0                          | $1 \times 10^{-15}$   | <15                      |
| 500                        | $1.5 \times 10^{-15}$ | <16                      |

Noise performance measured using Canberra Model 2020 Spectroscopy Amplifier set at 2  $\mu$ s unipolar, near-Gaussian shaping.

## Performance

INTEGRAL NONLINEARITY –  $< \pm 0.02\%$  for up to  $\pm 10$  V output.

GAIN DRIFT –  $< \pm 0.01\%$  per  $^{\circ}\text{C}$  ( $\pm 100$  ppm/ $^{\circ}\text{C}$ ).

NOISE OUTPUT PERFORMANCE – See Table 1.

CHARGE SENSITIVITY – 4.5 mV/pC or 22.7 mV/pC, internally selected.

HIGH CHARGE RATE CAPABILITY – Up to 9  $\mu\text{C/s}$ .

## Connectors

POWER – Amphenol 17-20090.

DETECTOR INPUT, TEST INPUT, ENERGY OUTPUT – BNC.

3 m (10 ft) compatible preamplifier power cable with required connectors is supplied with the preamp.

## Power Requirements

|                  |                 |
|------------------|-----------------|
| +24 V dc – 20 mA | +12 V dc – 2 mA |
| –24 V dc – 14 mA | –12 V dc – 2 mA |

## Physical

SIZE – 7.6 x 10.2 x 4.4 cm (3 x 4 x 1.75 in.).

NET WEIGHT – 0.31 kg (0.69 lb).

SHIPPING WEIGHT – Approximately 0.48 kg (1.06 lb).

## Environmental

OPERATING TEMPERATURE - 0 to 50 °C.

RELATIVE HUMIDITY - Up to 80%, non-condensing.

Tested to the environmental conditions specified by EN 61010, Installation Category I, Pollution Degree 2.

## B. Installation Considerations

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This unit complies with all applicable European Union requirements.

Compliance testing was performed with application configurations commonly used for this module; i.e. a CE compliant NIM Bin and Power Supply with additional CE compliant application-specific NIM were racked in a floor cabinet to support the module under test.

During the design and assembly of the module, reasonable precautions were taken by the manufacturer to minimize the effects of RFI and EMC on the system. However, care should be taken to maintain full compliance. These considerations include:

- A rack or tabletop enclosure fully closed on all sides with rear door access
- Single point external cable access
- Blank panels to cover open front panel Bin area
- Compliant grounding and safety precautions for any internal power distribution
- The use of CE compliant accessories such as fans, UPS, etc.

Any repairs or maintenance should be performed by a qualified Canberra service representative. Failure to use exact replacement components, or failure to reassemble the unit as delivered, may affect the unit's compliance with the specified EU requirements.

## Warranty

Canberra (we, us, our) warrants to the customer (you, your) that for a period of ninety (90) days from the date of shipment, software provided by us in connection with equipment manufactured by us shall operate in accordance with applicable specifications when used with equipment manufactured by us and that the media on which the software is provided shall be free from defects. We also warrant that (A) equipment manufactured by us shall be free from defects in materials and workmanship for a period of one (1) year from the date of shipment of such equipment, and (B) services performed by us in connection with such equipment, such as site supervision and installation services relating to the equipment, shall be free from defects for a period of one (1) year from the date of performance of such services.

If defects in materials or workmanship are discovered within the applicable warranty period as set forth above, we shall, at our option and cost, (A) in the case of defective software or equipment, either repair or replace the software or equipment, or (B) in the case of defective services, reperform such services.

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